Main Injector Rookie Book

Introduction and History

In the early 1980s, the Tevatron, an accelerator using superconducting magnets, was built and installed in the space directly below the Main Ring. The Main Ring was now relegated to handing over its protons to an even more powerful accelerator. Beam was transferred from the Main Ring to the Tevatron at 150 GeV, and the experiments received protons from the Tevatron at 800 GeV. The placement of both accelerators in the same tunnel saved millions of dollars in civil construction costs.

In the mid-1980s, the business of experimental particle physics took a step forward with the development of colliding beams, in which particles (at Fermilab, protons) would circulate in one direction and collide with corresponding antiparticles (antiprotons) traveling in the opposite direction. The center-of-mass energy released in collisions was far greater than anything that extraction to stationary targets could provide.

Antiprotons, unlike protons, are not yet found in gas bottles, but are created when high-energy protons strike an appropriate target. The Main Ring acquired an additional role to provide 120 GeV protons to the antiproton production target. The antiprotons were created at an energy of 8 GeV; they were then stored in the Accumulator Ring of the Antiproton Source. The 8 GeV antiprotons could then be injected into the Main Ring, accelerated to 150 GeV, and sent on to the Tevatron.

In time, it was realized that having the Main Ring and the Tevatron in the same tunnel was more of a liability than an advantage. The construction of two gigantic particle detectors internal to the Tevatron forced a redesign of the Main Ring, since overpasses had to be built to carry beam up over the experiments. However, the vertical distortion impaired Main Ring performance, even as the losses leaking from Main Ring continued to degrade the data being taken by the detectors. Moreover, stray magnetic fields from the Tevatron interfered with those of the Main Ring and hurt the beam quality even further.

It was eventually decided that the functions performed by the Main Ring would be better served by constructing a new accelerator outside the four-mile tunnel. This machine, to be called the Main Injector, would be a smaller, faster, and more efficient version of the Main Ring, and it would not stand in the way of the Tevatron. It would do everything Main Ring had done: accepting 8 GeV particles from the Booster or the Antiproton Source and accelerating them to 150 GeV, and accelerating 120 GeV protons at a rapid rate for antiproton production. In addition, the original role of the Main Ring, that of extracting beam directly to the experiments, would be restored, this time at 120 GeV.

Perhaps out of fear that building an accelerator with such a multitude of functions would not be sufficiently challenging, it was decided to add a second machine to the Main Injector tunnel. It would be known as the Recycler, because it would salvage scarce antiprotons from the Tevatron once data taking was complete. It would be built of non-powered permanent magnets, and would store the antiprotons at 8 GeV.

Intention

The intention of this book is to describe the Main Injector and Recycler and at a level which will be operationally useful.

The first chapter, “Modes of Operation,” will outline the geography, names, and places that pertain to the Main Injector. It will also describe, in a superficial way, the specific roles that Main Injector and Recycler will play: acceptance of 8 GeV beam from the Booster or Antiproton Source, acceleration of 120 GeV beam for antiproton production, extraction to the Fixed Target experiments, 150 GeV extraction into the Tevatron, and deceleration of antiprotons destined for the Recycler. The chapter will be an introduction to basic concepts and will provide context for the more detailed information to follow.

Chapter 2, “Magnets and the Lattice,” describes the many kinds of magnets used in the Main Injector ring and how they work together to get the beam to circulate. Chapter 3 deals with the power supplies for the magnets. Chapter 4 describes the water systems used for cooling the magnets, and Chapter 5 is about the vacuum systems, which clear the air molecules from the path that the beam must travel.

There will be more chapters released in the near future. Chapter 6, “Beam Diagnostics,” will explain how we can look at the beam and see what it is actually doing. Chapter 7, “Beam Transport Lines,” describes how beam is transferred from one accelerator to another. Incomplete versions of these two chapters are available in the Main Control Room copies of the rookie book, but are not deemed ready for mass release.

Future chapters will tackle the “RF” (radio frequency) systems, which accelerate the beam and perform complex manipulations of the beam during certain modes of operation.   The chapter on “Controls” will examine the communication of command and data information between the Main Injector and the Main Control Room. A chapter on “Utilities” will be concerned with the “mundane” aspects of the Main Injector infrastructure such as electrical power, ventilation, and water drainage, the failure of which can bring down an accelerator just as easily as the most complex instrumentation.

What To Look For

It is helpful, when reading this book, to recognize that the many complicated systems described are all directed toward a single goal, to maximize the production of the rare, exotic, and transient particles that are the domain of high-energy physics. From the standpoint of accelerator performance, that goal can usually be interpreted as the need to optimize intensity and/or luminosity.   Of course, there are issues of beam quality as well.

Intensity is defined as the number of particles reaching the desired target. In Fixed Target mode, where beam is extracted to stationary targets, intensity is usually the bottom line.

In Collider Mode, where proton and antiproton beams collide with each other, luminosity is usually the most important goal. Luminosity is a measure of the collision rate, which depends not only on intensity but also on beam size and quality.

Experience

I hope that this book will assist the reader in attaining these goals. However, it cannot be read in isolation. For those responsible for running the Main Injector, it is not a substitute for experience. The material in the book is only a tiny fraction of what is required from a competent operator or user of the machine. When devices are discussed, find them in the field. Go to the service buildings and take advantage of access time in the tunnels. Learn your way around the applications pages and seize opportunities to troubleshoot and tune the accelerators. This book is only a first step.